SOME ELEMENTS ABOUT A LONG-TERM COLLABORATION BETWEEN V.N. BAIER AND LAL-ORSAY

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SOME ELEMENTS ABOUT A LONG-TERM COLLABORATION BETWEEN V.N. BAIER AND LAL-ORSAY

ABSTRACT

- **Knowing the pioneering role and the strong interest of V.N. Baier on colliding beams physics, he has, more than once, been the guest of LAL. First of all, in the seventies, he spent some time in the Colliding Ring group, collaborating on different aspects of beam physics. Later on, from the beginning of the nineties, he visited LAL many times contributing to give a decisive impulse to the researches on positron sources using channelling radiation in oriented crystals. His main contributions on these subjects during his French stays are reminded.**

SOME ELEMENTS…

- **INTRODUCTION**
- **The exchanges between V.N. Baier and LAL- Orsay started in the framework of the collaboration between the INP-Novosibirsk and LAL . Such collaboration was strongly linked with the birth of the colliding beam rings. Pioneering works in USA, Russia and Europe gave the occasion of fruitful meetings and discussions. V.N. Baier played an essential role, with G.I. Budker, in supporting e-e+ collisions. So, French particle and accelerator physicists were strongly motivated in welcoming V.N. Baier in Orsay. He visited many times LAL and was first the guest of the Colliding Ring group headed by P. Marin. When the first proposition of a positron source using channeling was presented by the Orsay group, it was natural for developing this idea to look for a collaboration with the theory group of Baier-Katkov-Strakhovenko whose works were well known.**

SOME ELEMENTS ABOUT A LONG TERM COLLABORATION BETWEEN V.N. BAIER AND LAL-ORSAY

1- COLLABORATION AROUND THE COLLIDING BEAMS RINGS

Rapid recall:

The idea of colliding beams appeared first with the articles of D.W. Kerst et al [Phys.Rev 102 (1956)590], G. O'Neill [Phys.Rev102 (1956) 1418]. V.N. Baier gave a large description of the physics foreseen with such devices; for instance for electron-positron collision, the creation of elementary particles (π^0, π^+, π^-, μ^+, μ^-, K^+, K^-,.)➔ in Soviet Physics Uspekhi vol.5, May-june 1963

He gave an interesting overview of the genesis of the colliding rings physics in an article ➔ arXiv.hep-ph/0611201v1_15Nov.2006; in this article he reminded particularly the evolution of the interest of e-e- collisions (first studied machine) to e+e- collisions➔ VEPP-2 and the role played by G.I. Budker, A.N. Skrinsky and himself in the building up of the colliding rings in Novosibirsk since 1961.

SOME ELEMENT ABOUT A LONG TERM COLLABORATION BETWEEN V.N. BAIER AND LAL-ORSAY

- **1-COLLABORATION AROUND THE COLLIDING BEAM RINGS**
- **Studies on radiative polarization (Sokolov-Ternov) were worked out at Novosibirsk ; V.N. Baier, V.M. Katkov and V.M. Strakhovenko have published many articles on the subject {See Phys.Lett.31A (1970)198 and Soviet Phys. JETP 31(1970)908 }.**
- **V.N. BAIER visited the storage ring group at LAL in 1976 and collaborated with the physicists of this group. At that time, the first ring ACO was still working and DCI was being commissioned. The polarization has been measured on ACO for a positron beam in 1971. The depolarization at integer resonance (494 MeV) was also observed. V.N. Baier paid attention to the experimental results concerning polarization in the rings and gave a seminar untitled: Radiative Polarization (especially with regard to high energy machines).**
- **Contacts followed with LAL physicists as Jacques Haissinski and Jean Buon on problems regarding the colliding beams.**

SOME ELEMENTS…

- **2-CHANNELING RADIATION AND POSITRONS**
- **At the end of the eighties, a group from Orsay proposed to replace the magnetic undulator by a crystal to create an intense beam of photons; the proposition was presented at PAC 1989**
- **An hybrid source using an atomic undulator (Proc. of PAC, Chicago, 1989)**
- **R. Chehab, A. Artru, F. Couchot, A.R. Nyaiesh, F. Richard**

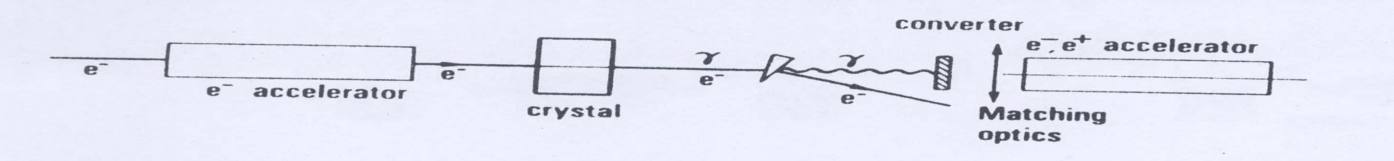

Figure 6 : Layout of a positron source using channeling

Simulations of an hybrid source made of Ge or Si crystals as radiators and amorphous W as converters:
For Ge and Si crystals oriented on <110> axis and 1 cm thick, we had e+ accepted yields of 0.5 to 0.6 e+/e- for 0.5 Xo thick converter and 1.2 to 1.3 e+/e- for 1 Xo thick; the incident e- energy is 20 GeV

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- **In order to test the idea of the positron source using channeling, it was important to carry out a proof-of-principle and to measure the characteristics of the produced photons and positrons. In 1990, V.N. Baier was visiting LAL for 2 months and a document has been written recommending to realize such proof-of-principle experiment.**
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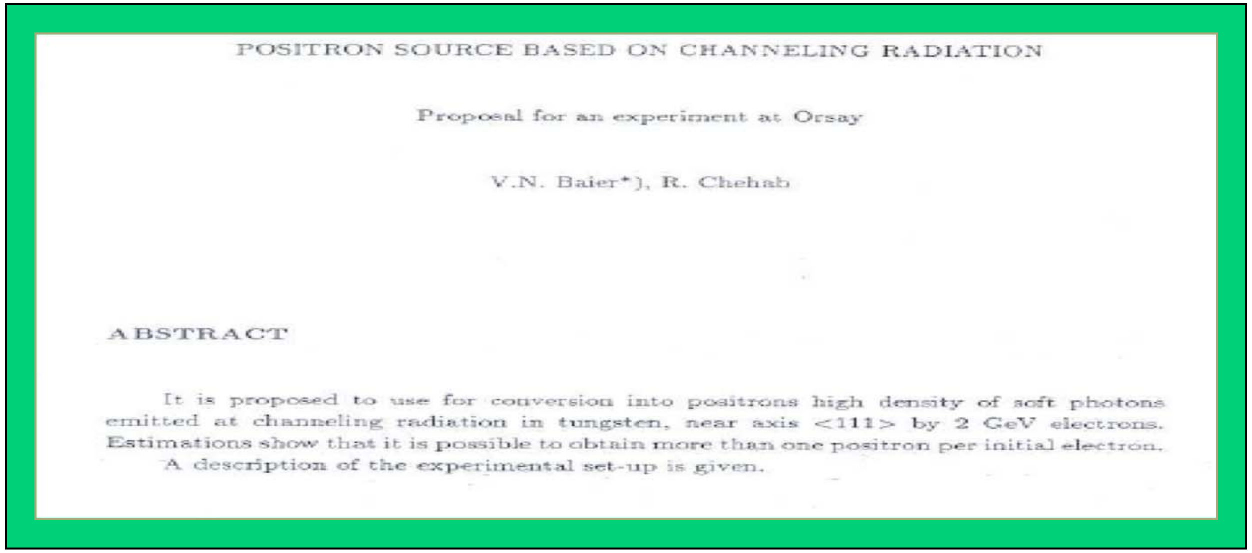

POSITRON SOURCE BASED ON CHANNELING RADIATION

Proposal for an experiment at Orsay

V.N. Baier*), R. Chehab

ABSTRACT

It is proposed to use for conversion into positrons high density of soft photons emitted at channeling radiation in tungsten, near axis <111> by 2 GeV electrons. Estimations show that it is possible to obtain more than one positron per initial electron.
A description of the experimental set-up is given.

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- **The Physical motivations:**

It is possible to use the described above specific characteristics of the channeling radiation (CR) in tungsten for a positron source. The following features of CR are the most important :

1. Increase of the total intensity of the radiation ($R \simeq 3$ at $\epsilon = 2$ GeV). The ordinary bremsstrahlung will also contribute (at the channeling conditions it is slightly changed[6]).

2. Compression of the CR spectral distribution (the intensity spectral distribution of CR at $\epsilon = 2$ GeV covers $\sim 1/8$ of the energy interval, while in the case of the bremsstrahlung intensity, the spectral distribution covers the whole energy interval).

It should be noted, that relatively soft photons are the most important for the positron source.

So we propose an experiment at the Orsay 2.3 GeV linac using electron beam with energy $\epsilon = 2$ GeV and tungsten crystal oriented along axis <111> (this is the "most strong" axis). Photons with energy $\omega \leq 250$ MeV will be radiated mostly due to CR (the density of these photons is ~ 20 times higher than in amorphous tungsten with the same thickness). Photons emitted will produce electron-positron pairs via

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THE PROPOSED EXPERIMENTAL SCHEME

2 GeV e-

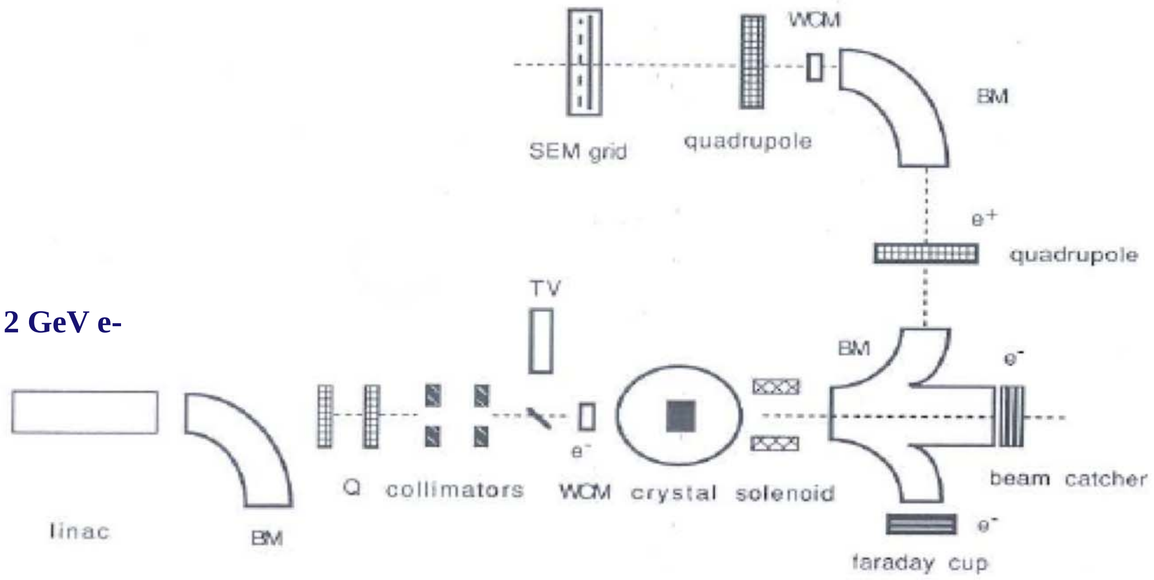

Figure 1 LAYOUT OF THE POSITRON SOURCE

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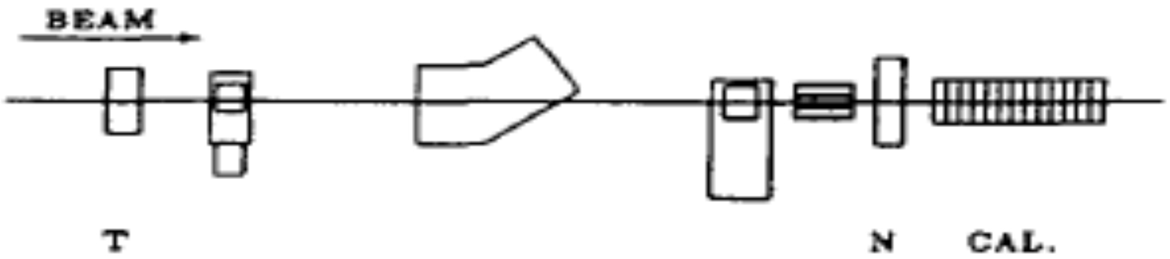
- **PROOF OF PRINCIPLE AT ORSAY (Photons only)**



T: induction monitor
G: goniometer+crystal
A: bending magnet
P: profile monitor (SEM grid)
C: collimator
N: scintillator
CAL: calorimeter

Fig. 10. Lay-out of the channeling experiment at Orsay.

The idea supported by V.N. Baier led to a simplified scheme where only the photons were measured. Such experiment was done in 1992-93 by French physicists with participation of a BINP colleague (T. Baier)

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- **THE RESULTS OF ORSAY EXPERIMENT**

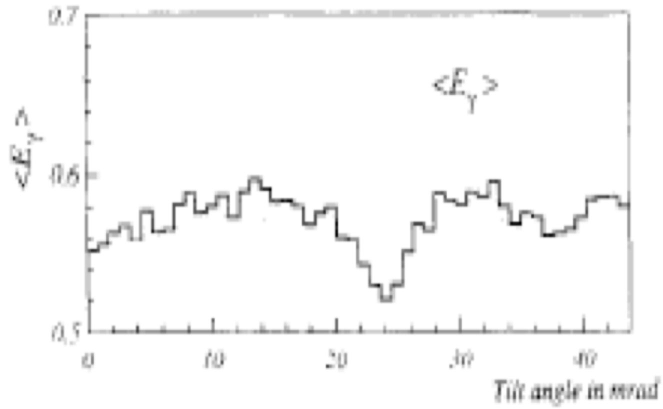

Fig. 12. Average photon energy, in arbitrary units, versus tilt angle between ⟨111⟩ axis and electron beam for an incident energy of 2 GeV. Rotation axis is the vertical one, the collimation angle is 1 mrad (from Ref. [14]).

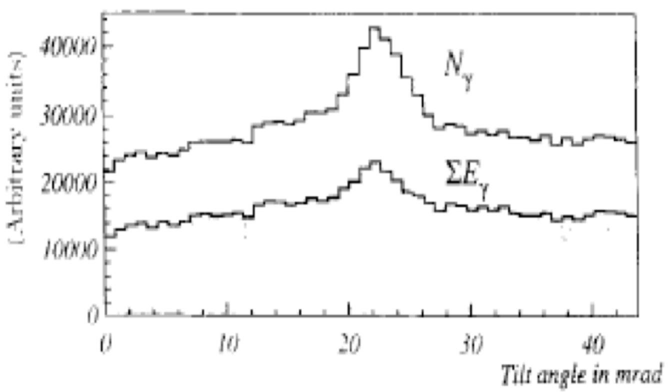

Fig. 11. Photon yield and radiated energy from a 1 mm thick tungsten crystal versus tilt angle between ⟨111⟩ axis and electron beam for an incident energy of 2 GeV. Rotation axis is the vertical one, the collimation angle is 1 mrad (from Ref. [14]). Both curves are represented in arbitrary units for the vertical scale.

On the W crystal <111> axis, we observed an enhancement in the production of soft photons with respect to random regime (amorphous). Analysis of results corresponding to low E- values (E- ~1 GeV) showing local minima on both sides of the peak (due to the combined effects of doughnut scattering and photon collimation) was discussed with our theoreticians colleagues of Kharkov (N. Shul'ga et al)

SOME ELEMENTS…

INTENSIVE SIMULATIONS ON A POSITRON SOURCE USING CHANNELING

- **Positron source using channeling in a tungsten crystal**

- **X. Artru[a], V.N. Baier[b], R. Chehab[c], [*] and A. Jejcic[d]**
- aInstitut de Physique Nucléaire - IN2P3-CNRS, 69622 Villeurbanne Cedex, France
- bBudker Institute of Nuclear Physics, Siberian Branch of Academy of Sciences of Russia, 630090 Novosibirsk, Russian Federation
- cLaboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université de Paris-Sud, 91405 Orsay Cedex, France
- dCollège de France, IN2P3-CNRS, Laboratoire de Physique Corpusculaire, 11 Place Marcelin Berthelot, 75231 Paris Cedex 05, France

- Received 22 January 1993;
- revised 29 December 1993.
- Available online 22 October 2002.

- **Abstract**
- A non-conventional positron source using 1.5–20 GeV electron beam impinging on a tungsten crystal oriented along its 111 axis is described. Computer simulation taking into account photon creation in the crystal, positron generation in a subsequent amorphous target and also positron capture and transport, allowed extensive investigation of this novel type of source. The possible performances are discussed hereafter. Positron yield has been calculated for different operating conditions. Comparisons with classical sources are presented.

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- **Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment**
  Volume 344, Issue 3, 15 May 1994, Pages 443-454

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RESULTS OF THE SIMULATIONS (Photons)

Simulations using the program of X. Artru on crystal effects {NIMB 48(1990)278} associated to GEANT code provided results on photons and e+e- pairs. An interesting feature concerns the photon production in an axially oriented crystal and in an amorphous target of the same thickness. Here, a thin target – 1 mm – has been considered.

When comparing the photon spectra with aligned and random (amorphous) crystal, it is seen a predominance of soft photons due to channeling effect.

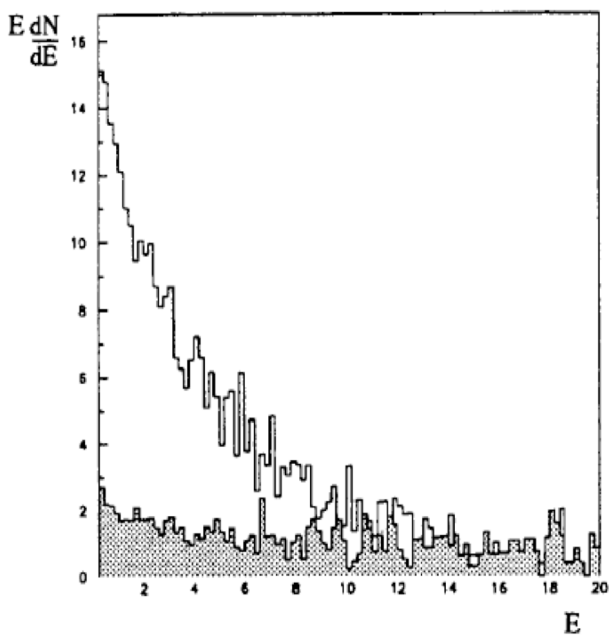

Fig. 13 Photon spectrum for incident electron energy of 20 GeV. Tungsten on <111> axis – 1 mm thickness

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- **THE CERN EXPERIMENT: WA 103**
- **A FRUITFUL COLLABORATION BETWEEN FRANCE AND RUSSIA LED TO A DECISIVE EXPERIMENT AT CERN → WA 103**

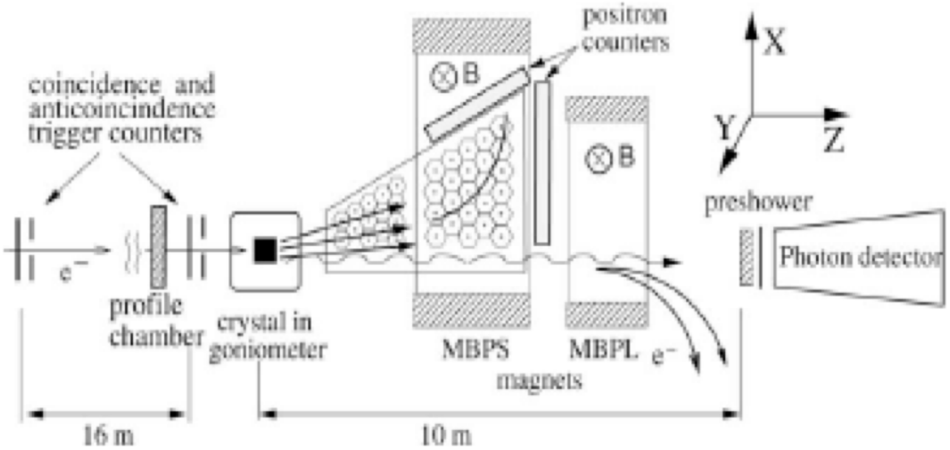

Fig. 1. The setup scheme. Drift chamber in two parts. DC1 is outside the magnetic field. DC2 is in the magnetic field of MBPS magnet. MBPL is the sweeping magnet.

An essential contribution was brought by BINP for the theoretical (BKS) and experimental (S. Serednyakov group) parts.

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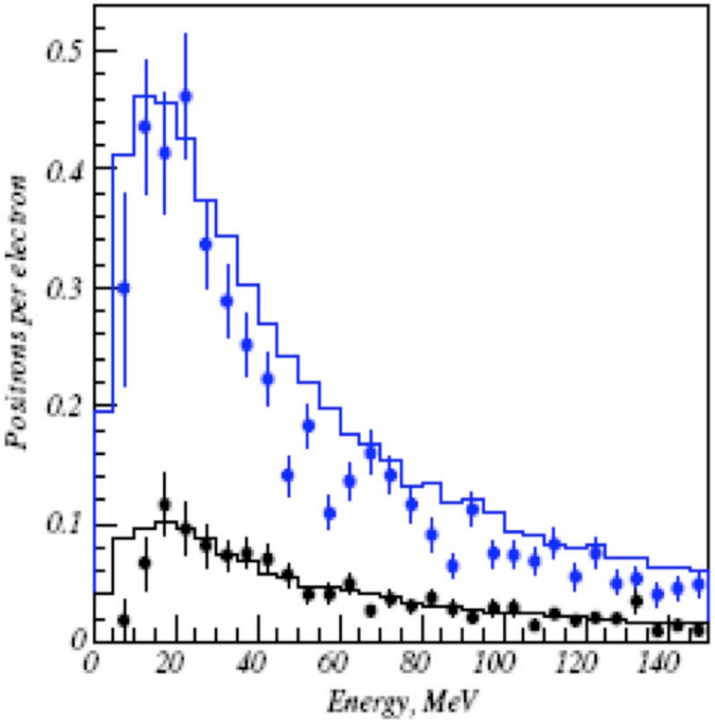
- **EXPERIMENTAL RESULTS [WA 103]**
- **The photon as the positron production**
- **are enhanced on the <111> axis of the**
- **W crystal. These results are obtained**
- **for a 4 mm crystal and an incident**
- **energy of 10 GeV. The curves show**
- **an enhancement larger than 4 for**
- **the crystal wrt the amorphous**
- **target of the same thickness.**
- **NIMB 240 (2005) 762**

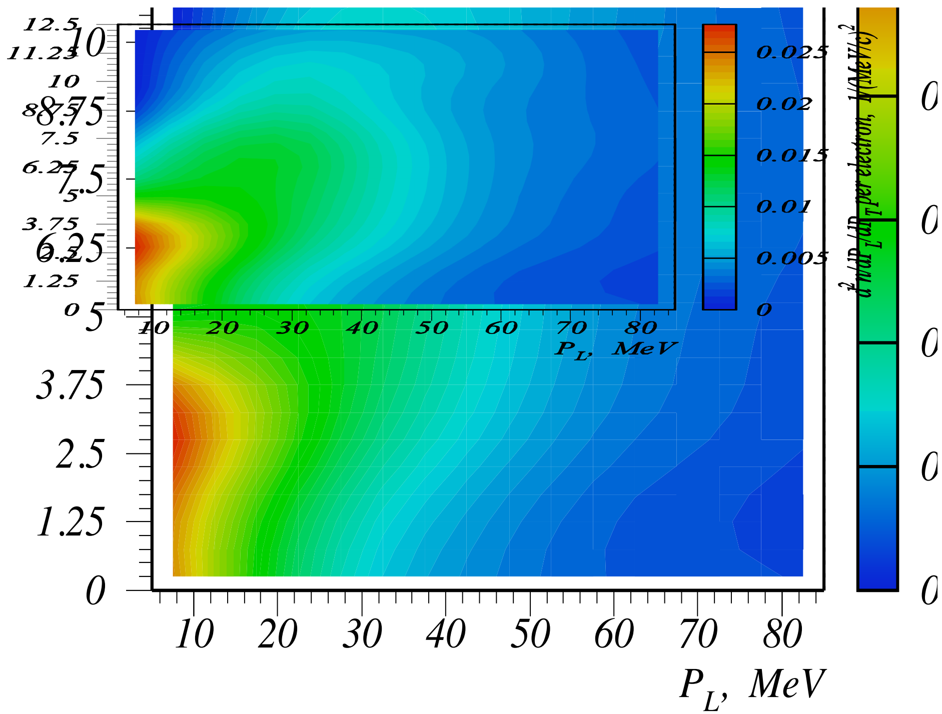


SOME ELEMENTS…

- ## THE POSITRON "PHASE SPACE"

THE EMITTED POSITRONS HAVE BEEN MEASURED IN A (p_L, p_T) DIAGRAMME; MOST OF THEM ARE IN A SOFT MOMENTUM REGION AND HAVE A LOW TRANSVERSE MOMENTUM; KNOWLEDGE OF THE MATCHING LENS PROVIDES THE EXPECTED YIELD.

On the figure, we have the case of a 8 mm crystal hit by a 10 GeV electron beam directed along the <111> axis.



SOME ELEMENTS…

- **PRODUCTION OF POLARIZED POSITRONS USING CHANNELING**
- **On a possibility of using crystals for the production of polarized positrons at high energies**

- **V.N. Baier [1*], R. Chehab[2] and V.M. Katkov[1,2]**
- [2]Laboratoire de l'Accelerateur Lineaire, IN2P3-CNRS et Universite Paris-Sud, F-91405 Orsay Cedex, France
- [1]Budker Institute of Nuclear Physics, 630090 Novosibirsk, Russian Federation

- Received 2 August 1993.
- Available online 28 October 2002.

Abstract

- Creation of longitudinally polarized high-energy positrons is considered at collision of high-energy photon with circularly polarized laser photon. A radiation of high-energy electrons in oriented crystals is proposed as a source of high-energy photons. Possible application is discussed.

- Using a circularly polarized laser (5 eV) and hard photons produced by energetic electrons (>50 GeV) channelled in oriented crystals, it is possible to obtain polarized positrons. The thickness of the crystal is of the order of a channeling radiation length at the incident energy [2mm in Si for E=250 GeV]

[*]Corresponding author.

- **Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment**
  Volume 338, Issues 2-3, 15 January 1994, Pages 156-160

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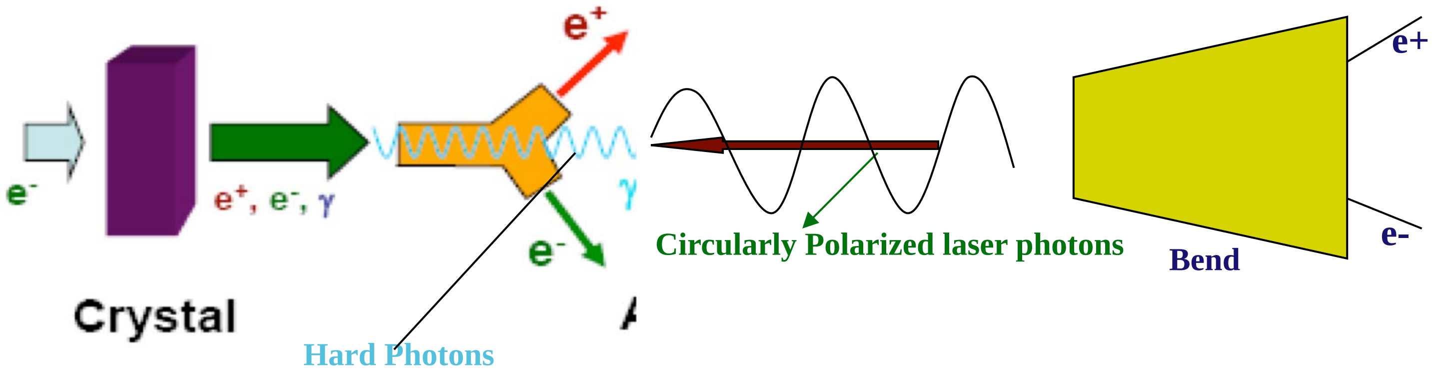
- **THE SCHEME FOR THE POLARIZED POSITRONS**



The pair creation process has a threshold defined by : $\eta = \omega\, \omega_0/m^2 = 1$. With ω_0 (laser) = 5eV, we need ω (crystal) = 50 GeV ➔ High energy incident e- beam on the crystal.
The angle of incidence of e- must be very small (θ < V/m, where V, potential:{Si: 70 eV; W: 417 eV]. The thickness of the crystal is adjusted to L_{ch} ~ 2 mm in Si at E- = 250 Gev
The charged particles are swept off after the crystal and only photons (ω) interact with the laser. Produced e+ are moving in the direction of e- incident beam. Selection of polarized positrons is done in appropriate energy window.

SOME ELEMENTS…

- **SUMMARY**
- **The collaboration between V.N. Baier and the LAL- Orsay with extension to other laboratories from IN2P3 (IPN-Lyon, L, PC-College de France) has been very useful due to the theoretical contribution of V.N. Baier and his nearest collaborators V.M. Katkov and V.M. Strakhovenko in many domains of high energy physics.**
- **We had also very useful opening collaborations with other groups from BINP, like that of Prof. S. Serednyakov. The latter group contribution has been essential for our experiment WA 103 at CERN.**
- **The constant support of Vladimir Nikolaevich in our activity on channeling was efficient and every time available.**
- **The collaboration with the Theory group of BINP is going on.**

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- **Acknowledgements**
- **I am particularly indebted to Xavier Artru and Vladimir Strakhovenko for their collaboration in preparing this talk.**

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- **ADDITIONAL: GENESIS OF THE COLLIDING BEAM RINGS**

*** 1956: Papers of Kerst, Cole, Laslett, Sessler, Symon in Phys.Rev. 102**

- **Paper of O'Neill in Phys.Rev. 102**

*** 1958: Proposal of Stanford (Panofsky, Richter)**

*** 1960: AdA/Frascati: Bernardini, Touschek, Ghigo, Corrazza (Nuovo Cimento)**

*** 1961: transfer of Budker-Baier-Skrinsky from Moscow to Novosibirsk**

*** 1963: Moving AdA from Frascati to Orsay (injection of e+)**

➔ observation of Touschek effect (IBS)

*** 1963: ACO project presented at Dubna**

ADONE project presented at Dubna

VEPP-II was in mounting stage

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